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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/005

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

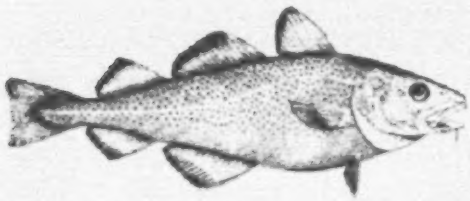

Image: Gadus morhua

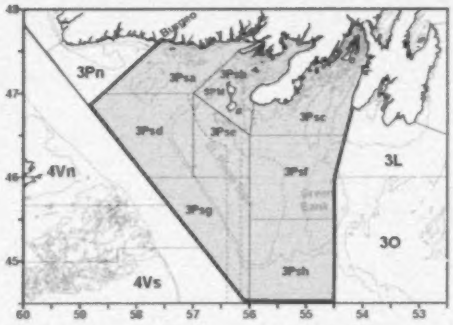

Figure 1: 3Ps management area (shaded) unit areas (solid lines) and economic zone around the French islands of St. Pierre et Miquelon (SPM) (dashed line).

Context:

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Fig. 1).

The distribution of NAFO Subdivision 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those from areas further northward. Female cod from this stock are generally maturing at younger ages in recent years. For example, about 50% of the females are mature by age 5 (~47 cm) in recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August, 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2014/15 management year was set at 13,225 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Fisheries Management Branch (Newfoundland and Labrador [NL] Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

Participants included Fisheries and Oceans Canada (DFO) scientists, a scientist from the French Research Institute for Exploitation of the Sea (IFREMER; France), fisheries managers, academia,

fishing industry representatives from Canada, and representatives from the province of NL and a non-government organization.

This Science Advisory Report is from the October 20-22, 2015 3Ps Cod Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The DFO Research Vessel (RV) survey covers most of the stock area and is designed to provide an index of stock size. Therefore, consistent with recent assessments, a cohort model (SURBA) based on this survey was used to infer overall stock trends.
- The stock is currently in the Cautious Zone as defined by the DFO Precautionary Approach (PA) Framework. The spawning stock biomass (SSB) has declined since 2012 and is currently estimated to be 41% above the limit reference point (LRP; $B_{Recovery} = SSB_{1994}$). The probability of being below the LRP in 2015 is low (p=0.05). Concern is expressed that there are few older fish in the SSB.
- Recruitment has improved over the last decade with most cohorts at or above the time-series (1983-2014) average. In particular, indications are that the 2011 and 2012 cohorts are strong.
- Estimated total mortality has generally been increasing since 1997 to near the time-series maximum. Over 2012-14, it averaged 0.65 (48% annual mortality), which is high especially considering that reported landings have been about half of the TACs over this time period.
- Projection of the stock to 2016 was conducted assuming mortality rates will be within ± 20% of current values (2012-14 average). Projected SSB increases in all cases (ranging from 23-46%) but remains within the Cautious Zone. These increases are driven by the relatively abundant 2011 year-class.
- Based on the Conservation Plan and Rebuilding Strategy adopted by Canada the calculated TAC for 2016/17 would be 13,043 t.
- Recent trends in mean size and weight-at-age, fish condition, and age-at-maturity are at or near their lowest observed levels, suggesting reduced productivity of this stock. This is consistent with broader ecosystem trends which also suggest decreased productivity.

INTRODUCTION

History of the Fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to a level of about 40,000 t during 1988-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August, 1993 after only 15,000 t had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year until the moratorium.

The fishery reopened in May, 1997 with a TAC of 10,000 t, and increased to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. Total Allowable Catches and landings over the past decade are shown in Table 1 and are described in detail below. The TAC

was set at 11,500 t for five consecutive management years (2009/10-2013/14) before increasing to 13,225 t for the 2014/15 management year and 13,490 t for the 2015/16 management year.

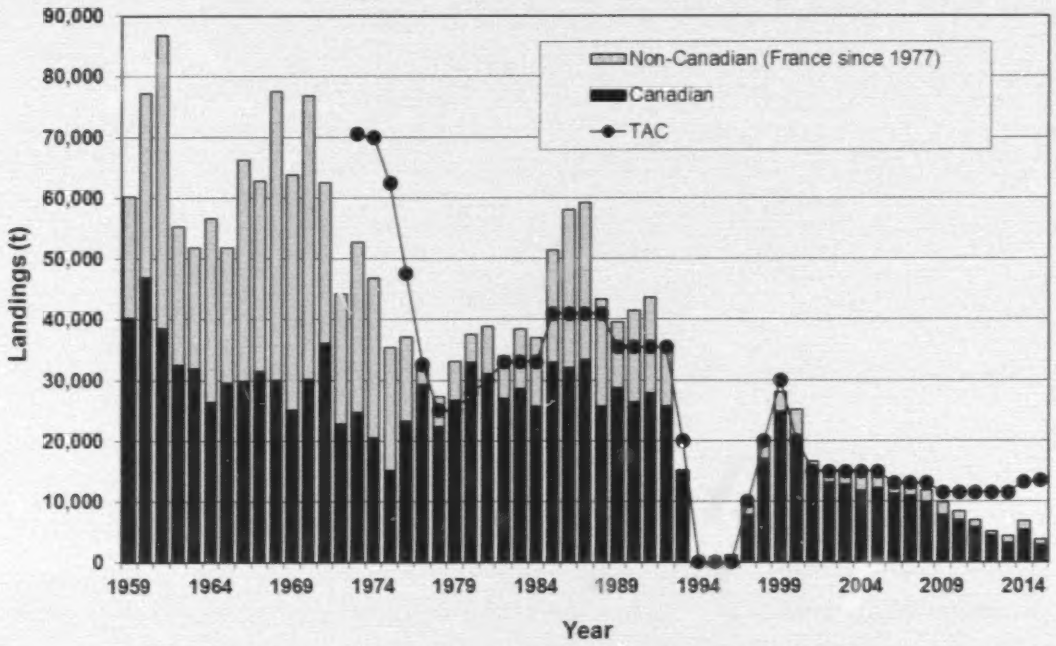

Figure 2: Reported annual landings and TACs (t) from 1959-2015. Values are based on calendar year from 1959-2000 and on management year (1 April-31 March) since then. Landings for 2015 (2015/16 season) are incomplete.

Landings

Table 1: Landings by management year (thousand metric tons).

Management Year	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14[1]	14-15[1,2]	15-16[1,2]
TAC[3]	13.0	13.0	13.0	11.5	11.5	11.5	11.5	11.5	13.225	13.49
Canada[4]	11.3	10.8	10.6	7.5	6.6	5.2	4.0	4.6	5.6	1.5
France	1.9	2.0	2.0	1.5	1.3	1.1	0.8	1.4	1.6	<0.1
Totals	13.2	12.8	12.6	9.0	7.8	6.3	4.8	6.0	7.2	1.5

[1] Provisional.
[2] Approximate landings to October 1, 2015.
[3] TAC is shared between Canada (84.4%) and France (St. Pierre et Miquelon; 15.6%).
[4] Canadian estimates after 2006/07 do not include recreational fisheries.

Reported combined landings by Canada and France have been substantially below the TAC since the 2009/10 season. During the 2014/15 season, approximately half (54%) of the 13,225 t TAC was landed. Prior to 2009/10, the TAC had been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons contributing to the recent reduction in landings, including economic factors and reduced cod availability. Of the 7,166 t landed during the 2014/15 season, 5,613 t was taken by Canada (including 13 t from sentinel surveys), and 1,553 t was landed by France.

Provisional data (as of October 1, 2015) indicate landings during the ongoing 2015/16 management year were 1,554 t, 48 t of which was landed by France. Although incomplete, these landings to date are relatively low, and suggest that much of the 2015/16 TAC of 13,490 t will likely not be caught.

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g. due to misreporting of catch by area and/or species) and downwards (e.g. due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium period. Given the uncertainty in the reliability of removal estimates during some periods, they are not used in the current analytical assessment.

During the 2014/15 season, approximately two-thirds of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

Species Biology

Stock structure and **migration patterns** of 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO RV trawl survey area. These features add uncertainty to the assessment of stock status. However, since the moratorium, new information has been obtained from various sources, including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several new measures to be put in place to reduce the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing has been delayed until April (beginning in 1993) and winter area closures have been imposed to reduce the potential for migrant non-3Ps cod being included in surveys and commercial catches. The area surveyed during the spring DFO RV trawl survey has also been extended shoreward and by 1997 the total area covered increased by 12%. The spring DFO RV trawl survey covers most of the stock so survey trends broadly reflect stock trends.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. The day at which 50% of fish have completed spawning has been variable, ranging from late March to early June. Detailed examination of fish collected from Halibut Channel (southern portion of 3Ps) in March-early May in 2015 suggested that spawning in this area began in April/early May in 2015. It was also noted for these fish that females initially categorized as spent were in fact likely skipping spawning, a phenomenon that may have influenced previous estimates of spawning time.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 has increased for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Growth, calculated from length at age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. Length at age during 2013-15 was among the lowest in the time series.

Comparison of post-1992 **condition** with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. There were signs of improved fish condition during 2008-13, but both gutted and liver condition have generally remained lower than that observed from the late 1990s to the mid-2000s. Condition values for 2014 and 2015 were among the lowest in the time series. Similarly, estimates of condition from sentinel sampling in recent years are below the time-series average.

ASSESSMENT

Resource Status

Sources of Information

A cohort model (SURBA) based on abundance indices from Canadian RV trawl surveys (1972-2015) is used to infer overall stock trends (Cadigan 2010). Additional sources of information are presented (see "Other Data Sources" below), but the current assessment model uses only the RV survey data because it is collected with a standardized design over most of the stock area and is thought to reflect overall trends in the stock.

Research Vessel Surveys

Canadian DFO RV bottom **trawl surveys** have been conducted in NAFO Subdivision 3Ps since 1972, however, surveys from 1972-82 had poor coverage. The surveyed area was increased by 12% by the addition of strata closer to shore in 1994 and 1997. The DFO RV survey was not completed in 2006.

Survey indices are presented for the expanded DFO survey area (inshore and offshore; denoted "All strata <300 ftm" in Figs. 3 and 4) as well as for the offshore strata ("Offshore <300 ftm" in figures). The DFO RV survey covers most of the stock distribution, and survey trends are considered to broadly reflect stock trends. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shoreward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but exhibits a downward trend from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period up to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. Biomass estimates in recent years have generally been low, with six of the last nine years being below the 1997-2015 average. Survey catches in 2015 were highest in the Halibut Channel, except for one unusually high survey catch on Burgeo Bank. Survey biomass from the expanded index ("All Strata <300 ftm") shows similar trends to the offshore-only index.

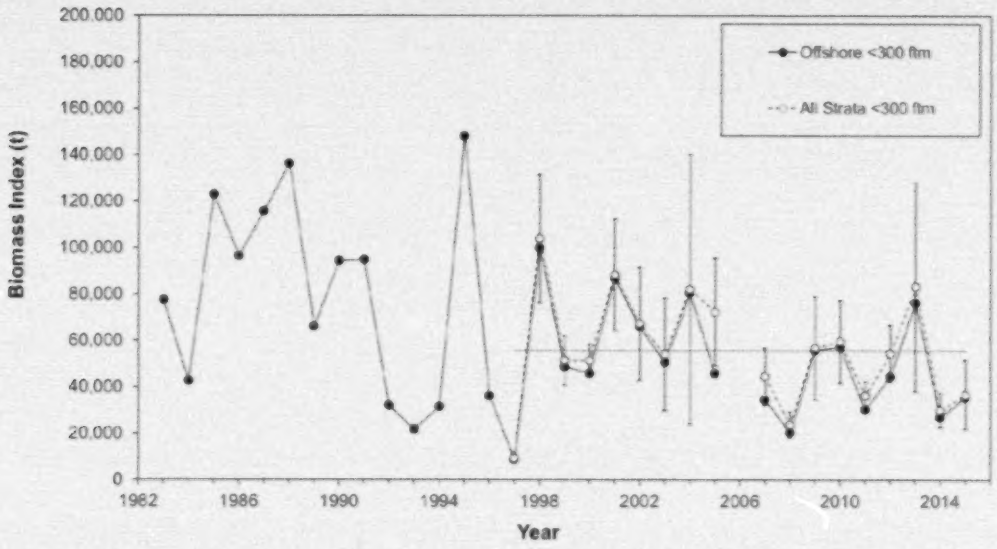

Figure 3: Research vessel survey biomass indices (t) (error bars are ± one standard deviation for combined survey index–dashed line is the time series average of the combined survey index).

The offshore DFO RV abundance index is at times variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 4). Abundance was low during the 2000s but has increased somewhat in recent years with six of the last seven years being at or above average. In particular, the 2013 estimate was very high but characterized by a high degree of uncertainty.

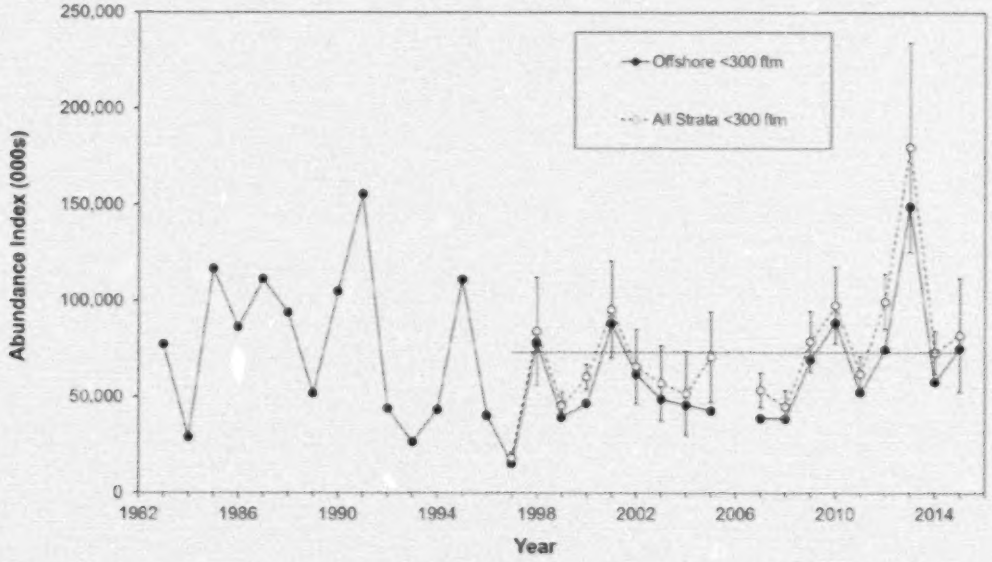

Figure 4: Research vessel survey abundance indices (error bars are ± one standard deviation for combined survey – dashed line is average of combined survey index).

Age Composition

Catches during the 2015 RV survey consisted mainly of cod aged 2-4 (80% of abundance index). Indications are that the 2011 (age 4 in 2015) and 2012 (age 3 in 2015) year classes are strong. The degree to which these two year-classes will contribute to future fisheries is as yet uncertain.

Cohort Analysis Reference Points

The LRP for this stock is $B_{Recovery}$, the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the LRP. The Upper Stock Reference (USR) has been defined as two times the LRP (see Management Considerations section). Removal reference points have not been identified for this stock.

Spawning Biomass

Cohort analyses of the RV data indicated that SSB declined by 58% over 2004-09 (Fig. 5). Median SSB was estimated to be below the LRP in 2009. SSB increased considerably over 2009-12 but has since declined. The 2014 and 2015 estimates are approximately 1.4 times higher than the LRP. The probability of being below the LRP in 2015 is low (~0.05). As a result of improved recruitment and recent increases in the proportion mature-at-age, 82% of the 2015 SSB is comprised of fish of ages 4-7. The reliance on young spawners may be a concern given that younger fish produce fewer and smaller eggs/larvae that may have reduced survival. Young fish also spawn over a narrower time frame which decreases the probability of overlap between larval emergence and peak plankton abundance and can result in reduced survival.

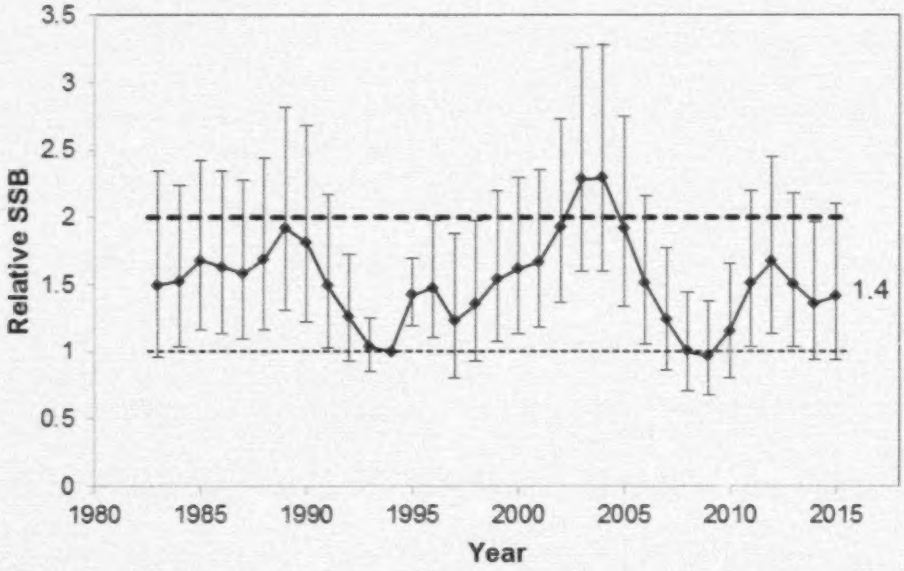

Figure 5: Cohort analysis estimates of SSB, relative to the 1994 value (median estimate with 95% confidence interval). A thin horizontal dashed line at one (reference level) represents the SSB Limit Reference Point and a thick horizontal dashed line at two represents the Upper Stock Reference (i.e., 2 x LRP). Text label indicates the current SSB relative to the LRP.

Mortality Rates

Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model (Fig. 6) for ages 5-10 has generally been increasing since 1997 and current

estimates are near the time series maximum. The average estimated mortality over the last three years (2012-14) is 0.65 (48% annual mortality), which is high especially considering that reported landings have been about half the TAC over this time period. The total mortality values are weighted by population number at each of ages 5-10.

This analysis assumes that age 4 and older fish are equally selected (flat-topped) by the RV survey. Alternate assumptions for the relative catchability (domed) of cod ages 4 + were explored in a previous assessment and gave similar trends (DFO 2009). Flat-topped selectivity is commonly assumed unless there is evidence otherwise.

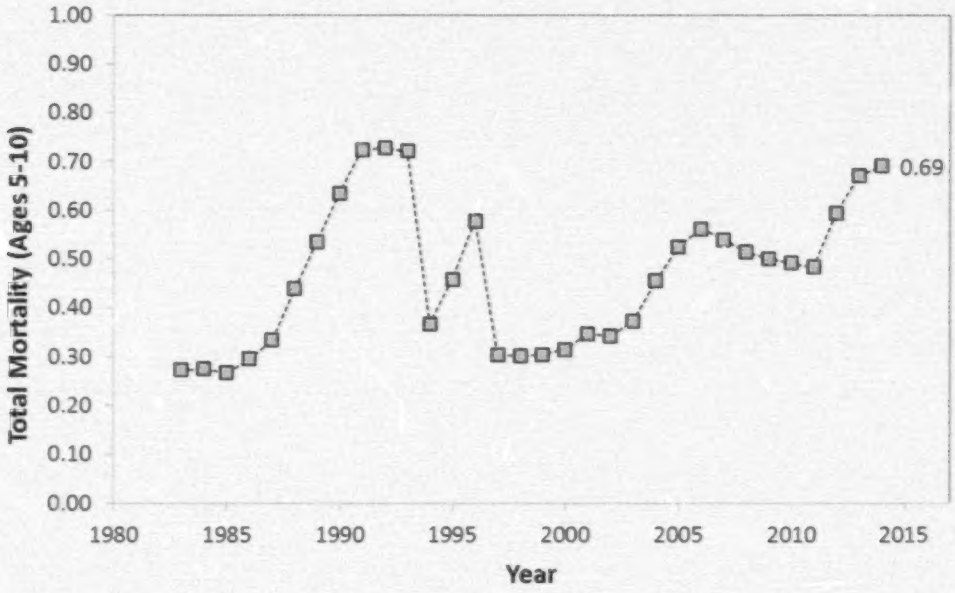

Figure 6: Cohort analysis estimates of population weighted average annual mortality (ages 5-10). Text label indicates the estimated total mortality for 2014.

Recruitment

Recruitment (Fig. 7) has improved over the last decade with most cohorts at or above the time series (1983-2014) average. Indications are that the 2011 and 2012 cohorts are strong. However, it should be noted that the uncertainty around the estimates for these recent cohorts is quite high and the estimates may be revised as additional data are collected.

Retrospective Pattern

The assessment of 3Ps cod has been subject to retrospective revisions of estimates from previous years with the addition of a new year's survey data. For example, in the 2013 assessment the SSB demonstrated a steadily increasing trend from 2009-13 with the 2013 estimate being twice the level of the LRP. In the 2014 assessment, however, SSB leveled off after 2012, with the 2013 estimate being 1.6 times the level of the LRP. In the 2015 assessment, the 2013 SSB estimate has been further downgraded to 1.5 times the level of the LRP. Likewise, the previous assessment estimated the 2014 SSB to be 1.6 times the level of the LRP, whereas this has been adjusted to approximately 1.4 times the LRP in the current assessment. Retrospective revisions are not uncommon in cohort models, which use annual information to predict the abundance of multiple cohorts. The relatively large revision to the SSB estimates occurred because the 2014 and 2015 survey estimates have decreased considerably

from the large (and unexpected) values of the 2013 survey. Several recent year-classes were revised downwards, with the greatest revision to the 2011 year-class.

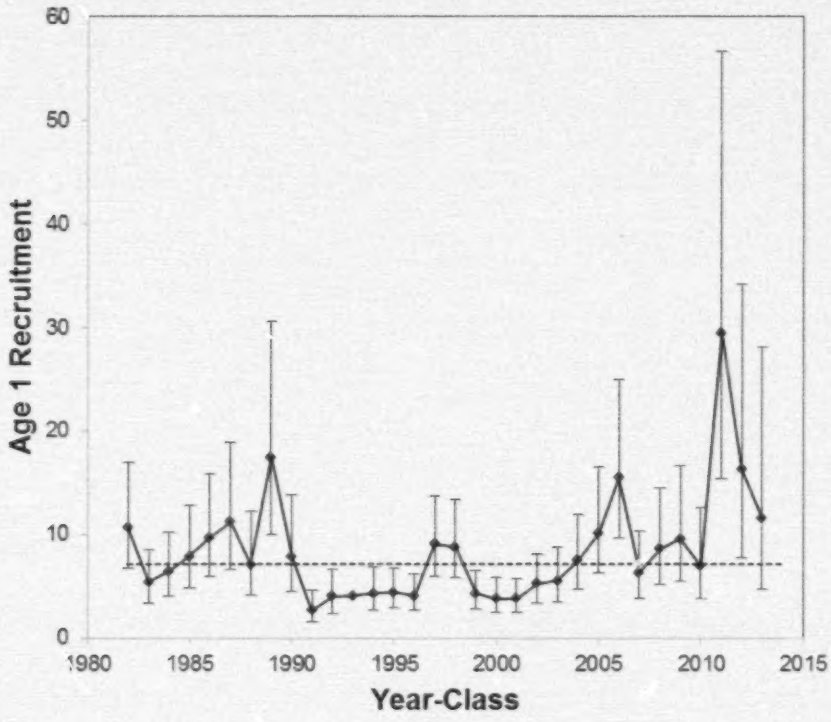

Figure 7: Estimated relative year-class strength from cohort model (median estimate with 95% confidence intervals). The dashed horizontal line is the time-series median.

Projection

Projection of the stock to 2016 was conducted assuming mortality rates will be within ± 20% of current values (2012-14 average). Projection scenarios indicate that the 2016 SSB will increase from the 2015 estimate, with median 2016 relative SSB projections ranging from 1.7 to 2.1. In each of the scenarios, the probability of being below the LRP in 2016 is low (≤ 0.05). By 2016 the strong 2011 year class will be 5 years old and under all projection scenarios examined will constitute at least 50% of the 2016 SSB, indicating an extremely high reliance of the population on very young spawners.

TAC Calculation

The Conservation Plan and Rebuilding Strategy adopted by Canada to guide management decisions includes Harvest Control Rules for calculating the TAC based on recent stock trends and current stock status. The TAC for the coming year is calculated by adjusting the current year TAC (2015/16=13,490 t) by some percentage change based on the trend in SSB.

When the SSB is within the Cautious Zone of DFO's Precautionary Approach Framework (as is currently the case for 3Ps cod) the rules are:

- No increase in the TAC will be considered above the 2011-12 level of 11,500 t until the SSB is at least 150% of B_{lim} and the recruitment index is at least 75% of the mean of the time series.
- TAC increases will not exceed the lesser of 85% of the percentage increase from the most recent 3-year average SSB, or 15%, unless the recruitment index is less than 75% of the mean of the time series, in which case the increase would be reduced by 1/2 of what it otherwise would have been.
- TAC decreases will not be less than 115% of the percentage decrease from the most recent 3-year average SSB, unless the recruitment index is at least 125% of the mean of the time series, in which case the decrease would be reduced by 1/2 of what it otherwise would have been.

Based on these rules, the calculated TAC for 2016/17 is 13,043 t. Note that these Harvest Control Rules have not been fully evaluated by DFO Science.

Other Data Sources

Other sources of information were considered in the assessment to provide perspectives on stock status in addition to the DFO survey indices. These sources of information include data from the Sentinel survey (1995-2014), science logbooks for vessels less than 35 feet (1997-2014) and logbooks for vessels greater than 35 feet (1998-2014). Results of a telephone survey of inshore Canadian fish harvesters and exploitation (harvest) rates estimated from tagging experiments in Placentia Bay (and more recently Fortune Bay) were also available. Any differences in trends between these other data sources and the DFO survey are difficult to reconcile but attributed to differences in survey/project design, seasonal changes in stock distribution, differing selectivity of various gear types, or the degree to which the various data sources track only certain subareas/ components versus the entire distribution of the stock.

Sentinel survey

Fixed gear sentinel surveys have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2015. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2015 is still ongoing; hence, the data for 2015 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 8).

The standardized total annual catch rate for gillnets was highest from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2014 (Fig. 8, upper panel). The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). More recent (2013, 2014) values are the lowest in the time-series.

The standardized age-specific catch rates for sentinel gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the sentinel catch rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is less clear, but generally indicates that they are relatively weak. Comparison of sentinel catch rates and the RV index at times

show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranks above average in the RV survey, but does not appear particularly strong in either sentinel index even though fish in this year-class are now available to these gears. The 2011 and 2012 year classes, which appear strong in the survey, are not yet fully selected by either of the Sentinel gears.

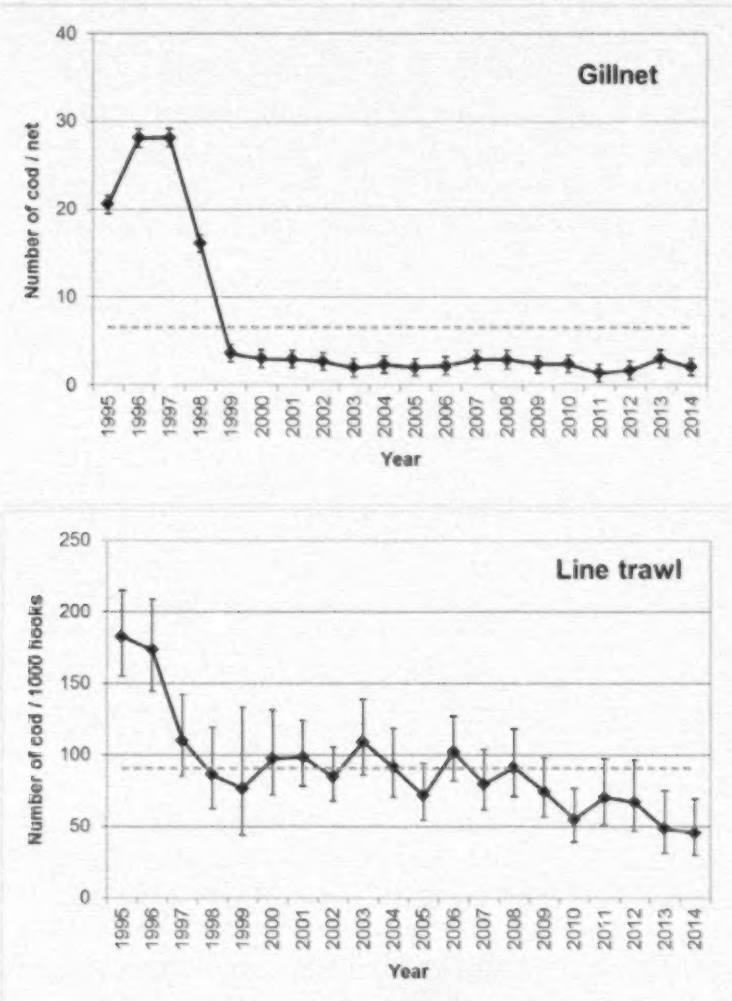

Figure 8: Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Logbooks

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in fishery performance or the nature of the fishery than changes in population size.

Logbooks for < 35' Vessels

Standardized annual catch rates from science logbooks (< 35' sector) for Canadian vessels fishing gillnets show a declining trend over 1998-2000, and remained relatively stable below the time series average up to 2013 (Fig. 9, upper panel). Catch rate was slightly higher in 2014 and

above the time series average. Line-trawl catch rates show a much different pattern with a greater degree of variation (Fig. 9, lower panel). After peaking in 2006, line-trawl catch rates generally declined and have remained relatively stable since 2009. The 2014 estimate is slightly above the time-series average. The commercial catch rate index is based on weight of fish caught whereas the sentinel index is based on numbers.

The percentage of the catch from the < 35' sector that is accounted for in the standardized logbook indices declined from 70% in 1997 to a time series low of 22% in 2011, followed by a subsequent increase to 42% in 2014. This likely affects the quality, and comparability, of this index over time, such that it is unclear if the CPUE trends reflect the fishery as a whole.

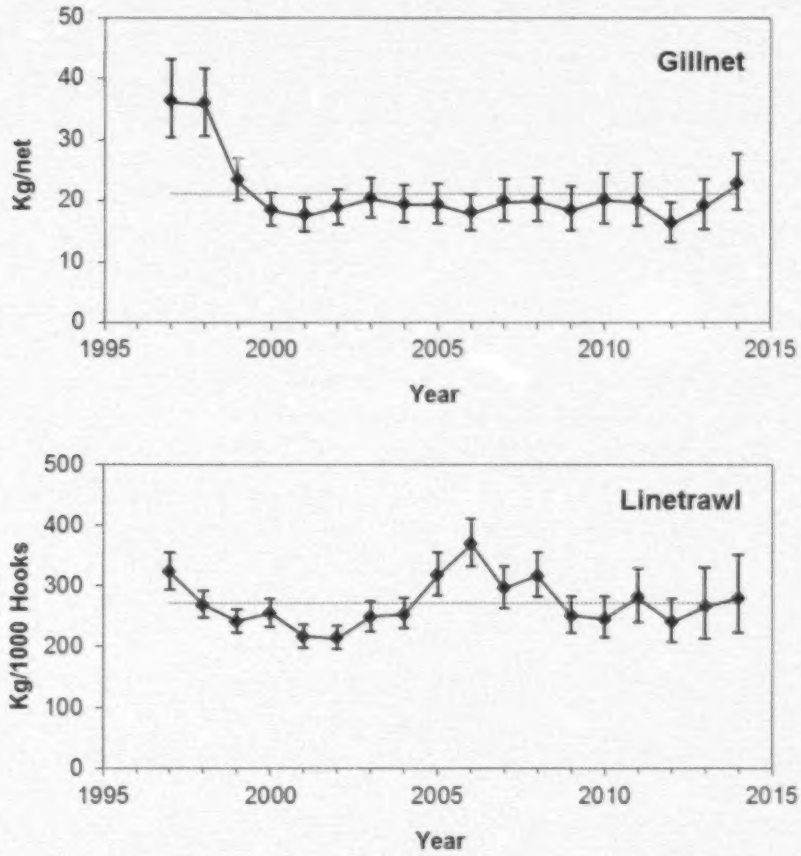

Figure 9: Standardized catch rates for gillnets and line-trawls from science logbooks for vessels < 35'. Error bars are 95% confidence intervals; dashed line is the time-series average.

Logbooks for > 35' Vessels

The spatial distributions of both landings and unstandardized catch rates over 1998 to 2014 were determined using logbook data from the > 35' fleet. Data on landings and catch rates for otter trawls, gillnets and linetrawls were analyzed. For all three gears, there was substantial spatial concentration in landings and a reduction in the number of areas reporting high landings over the time-series. From 1998 to 2010, catch rates in otter trawls were consistently high in the Halibut Channel and they were also high in areas of St. Pierre Bank during most years. Otter trawl catch rates declined in the Halibut Channel from 2010 to 2013. During 2014, limited effort

was reported by otter trawlers on St. Pierre Bank and while there was increased effort in the Halibut Channel, only low or moderate catch rates were reported there. Catch rates in gillnets were highest in Placentia Bay and on St. Pierre Bank from 1998 to 2007, but since 2007 the highest catch rates were typically reported only on the bank. Spatial trends differed between gillnets and linetrawls. Catch rates by linetrawls were variable without trend at most locations except in the Halibut Channel where catch rates were typically among the highest reported (> 1.0 kg per hook) up to 2010, but only low to moderate catch rates were reported there during 2013 and 2014. How trends in catch rates relate to stock status is unknown, particularly considering the substantial declines in effort.

Tagging

The geographical coverage of tagging since 2007 has been limited to inshore areas, which causes some uncertainty as to how results relate to the stock as a whole. The number of cod and areas where tagging was conducted was expanded from only 3Psc (Placentia Bay) to include 3Psb (Fortune Bay) in 2013 and 2014 and 3Psa in 2013. Although exploitation rates based on tagging of cod in these inshore areas may not be applicable to other areas, or to the stock as a whole, these inshore regions account for a significant portion (~ 50%) of the overall annual landings from the stock.

Exploitation rates for 2014 and updated estimates for 2013 were obtained. These incorporated annual estimates of tag reporting rates (~ 75% during 2013-2014) based on high-reward tagging. In 2013 and 2014, the harvest rates were generally similar (10-16%) among cod tagged in Placentia Bay or Fortune Bay; the only exception was among the larger cod (> 65 cm) tagged in Fortune Bay where harvest rates were higher (21%-25%). Harvest rates in 3Psa in 2014 were low (6%-8%) irrespective of cod size. The distribution of tag returns did not give any indication of significant exploitation of 3Ps cod in adjacent stock areas (3KL/3Pn-4R), although local movement of cod between 3Pn and western 3Psa, and between 3Ps and southern 3L, was evident.

Sources of Uncertainty

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium period. Given these uncertainties and the variability in the reliability of removals estimates, they are not used in the current analytical assessment. Assessment models do exist that are capable of handling uncertainty in the catch estimates but some information would still be needed in order to place reasonable bounds on the landings.

There is uncertainty regarding the origins of fish found in 3Ps at various times of the year. Tagging and telemetry experiments show that there is mixing with adjacent stocks (southern L and 3Pn4RS) and this may vary over time. However, results indicate that exploitation of fish tagged within Placentia Bay has been predominantly within that area, even after several years at liberty.

The geographical coverage of tagging since 2007 is limited to inshore areas; during 2008-11 cod were only tagged in Placentia Bay (3Psc). More recently, tagging has been expanded to other inshore areas (3Psb in 2012-14, 3Psa in 2013). The lack of recent tagging in other areas adds uncertainty to the understanding of natural mortality rates, exploitation rates, stock

structure, as well as movement patterns and how these influence survey and commercial catch rates in the recent period.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in a recent assessment and yielded a similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. There are strong indications that the 2013 survey may have been influenced by a year effect. In 2013, a large single catch of fish on Burgeo Bank resulted in > 50% of the overall biomass being located in this particular area and causing a large spike in the survey indices for that year. A similar phenomenon occurred in the 2015 survey with a single large set on Burgeo Bank accounting for 38% of the biomass index. The fact that single large fishing sets have heavily influenced survey indices in two out of the last three years is a concern for the assessment and the sporadic appearance of high numbers of fish on Burgeo Bank is not fully understood. Another clear sign of a year-effect is the fact that the 2013 RV survey estimated that the abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. For at least some cohorts, this change is largely influenced by the single large survey catch described above. The number of fish in a cohort cannot increase as it ages (without immigration) and when analyses suggest that such an increase has occurred it is considered evidence for a year effect. In the 2013 survey, the 2011 year class (age 2 fish) was estimated to be by far the strongest in the times series. The subsequent two assessments have downgraded the estimated strength for this year class but it still appears strong relative to other recent year classes.

The percentage of the catch from the < 35' sector that is recorded within the logbook database has declined over time and now represents only about 42% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality and comparability of the standardized catch rate index derived from these data over the time series.

Age at 50% maturity has been declining in recent years. The proportion of female cod maturing at younger ages has increased for all cohorts subsequent to the 1986 cohort, resulting in an increased proportion of young fish contributing to the SSB. It is uncertain whether or not these small, young fish are effective spawners.

CONCLUSIONS AND ADVICE

- The DFO survey covers most of the stock area and is designed to provide an index of stock size. Therefore, consistent with recent assessments, a cohort model (SURBA) based on this survey was used to infer overall stock trends.
- The stock is currently in the Cautious Zone as defined by the DFO PA Framework. The SSB has declined since 2012 and is currently estimated to be 41% above the limit reference point (LRP; $B_{Recovery}$=SSB_{1994}). The probability of being below the LRP in 2015 is low (p=0.05). Concern is expressed that there are few older fish in the SSB.
- Recruitment has improved over the last decade with most cohorts at or above the time-series (1983-2014) average. In particular, indications are that the 2011 and 2012 cohorts are strong.

- Estimated total mortality has generally been increasing since 1997 to near the time-series maximum. Over 2012-14, it averaged 0.65 (48% annual mortality), which is high especially considering that reported landings have been about half of the TACs over this time period.
- Projection of the stock to 2016 was conducted assuming mortality rates will be within ± 20% of current values (2012-14 average). Projected SSB increases in all cases (ranging from 23-46%) but remains within the Cautious Zone. These increases are driven by the relatively abundant 2011 year-class.
- Based on the Conservation Plan and Rebuilding Strategy adopted by Canada the calculated TAC for 2016/17 would be 13,043 t.
- Recent trends in mean size and weight-at-age, fish condition, and age-at-maturity are at or near their lowest observed levels, suggesting reduced productivity of this stock. This is consistent with broader ecosystem trends which also suggest decreased productivity.

OTHER CONSIDERATIONS

Management Considerations

The level of total removals is uncertain but less so in the post-moratorium period. In assessing stock status, it would be useful to better understand the accuracy of total removals. Accurate estimates of recreational fishery landings are also required.

Management should recognize that cod which overwinter in 3Ps are also exploited in adjacent stock areas (Division 3L and Subdivision 3Pn). Hence management actions in these stock areas should consider potential impacts on 3Ps cod. Consequences of area/time closures should be carefully considered as these may result in higher exploitation rates on the components of the stock that remain open to fishing. The fishery should be managed such that catches are not concentrated in ways that result in high exploitation rates on any stock components.

Management should be aware of within-year variations in the individual weight of cod. Greatest individual yield can be gained when fish are in peak condition, typically in late fall/early winter, while minimizing the total number of individuals removed from the stock.

When average fish size (age) in commercial catches is reduced through either depletion of older cohorts or recruitment of younger cohorts, the numbers of fish removed per ton of landed catch is increased.

A seasonal closure of the entire 3Ps stock area (typically March to mid-May) occurs annually and is intended to minimize fishing on spawning aggregations. Some harvesters have suggested that the time of spawning has been delayed in recent years and that the timing of the closure may no longer be appropriate. Fishing was permitted in March 2014 and 2015 to provide those harvesters with increased flexibility in accessing the resource. In 2015, fish collected from the Halibut Channel area (Southern 3Ps) by industry in March and from the DFO multispecies survey in April-May were examined in detail in order to evaluate cod reproductive status during the typical spawning closure time. Samples collected by industry suggested that fish in this region did not spawn in March in 2015 but some individuals were late in the development process and likely near the start of spawning. Data and biological samples from the 2015 DFO Survey (April/May) suggested spawning began sometime in April/early May. Modelling of the day at which 50% of female fish in the survey data were spent (D50) demonstrated annual variability in spawning time but no trend toward later spawning in recent years. It is important to note that these results apply to a specific area in a specific year and that

decisions regarding spawning closure times should consider the potential for spatial and interannual differences in spawning time.

Temperature and Physical Oceanography

Oceanographic information collected during the spring DFO RV surveys indicated that near-bottom temperatures throughout NAFO Subdivision 3Ps have been warming during the past two and a half decades, reaching two standard deviations above normal in 2011 and 2012 but decreasing to one standard deviation above normal in 2013-15. A further decrease to near-normal values was observed in waters depths <100 m on St. Pierre Bank in 2014-15. Survey catches of cod are generally lower in years where relatively large incursions of cold/fresh water from the eastern NL shelf dominate, indicating an apparent effect on cod distributions and their availability to the RV surveys. Furthermore, significant positive correlations were found between survey abundance and bottom temperatures in areas with water depths <100 m, mainly St. Pierre and Green Banks.

Ecosystem Considerations

NAFO Subdivision 3Ps can be characterized as an ecosystem production unit, but one that is heavily influenced by neighboring ecosystems (Grand Bank, Gulf of St. Lawrence, Scotian Shelf). This system has experienced an overall significant warming trend since the mid-1990s, although there is important variability around that trend.

The 3Ps fish community declined during the mid-1980s, and early-1990s; this decline was also accompanied by a decrease in average fish size. Since the mid-1990s, the overall fish biomass has remained relatively stable, but abundance showed a clear increase until 2013, and declined afterwards. These changes in overall abundance have been driven by planktivorous (plankton-eating) fishes, mostly sandlance and, to a much lesser extent, herring.

Underneath the overall stability in fish biomass since the mid-1990s, changes had occurred in average fish size and the composition of fish functional groups. After the decrease observed in the late-1980s, and early 1990s, average fish size remained relatively stable until the mid-2000s, when it experienced a further reduction, and it has remained at that lower level since.

In terms of composition of fish functional groups, Atlantic cod is an important and dominant species among piscivorous (fish-eating) fishes in 3Ps. However, since the late 2000s and early 2010s, its dominance level has lessened, and other species (mostly silver hake *Merluccius bilinearis*) increased their share of the overall piscivorous fish biomass (Fig. 10). Other species within this functional group that have experienced declines in biomass include the black and spiny dogfishes. Increases of "warmer-water" species like silver hake may be linked to the warming trend in this ecosystem. In addition to the changes within fish functional groups, the trends of some functional groups also show correlated patterns of increases and decreases between 1996 and 2015, which hints at the interconnectedness among ecosystem components within the region.

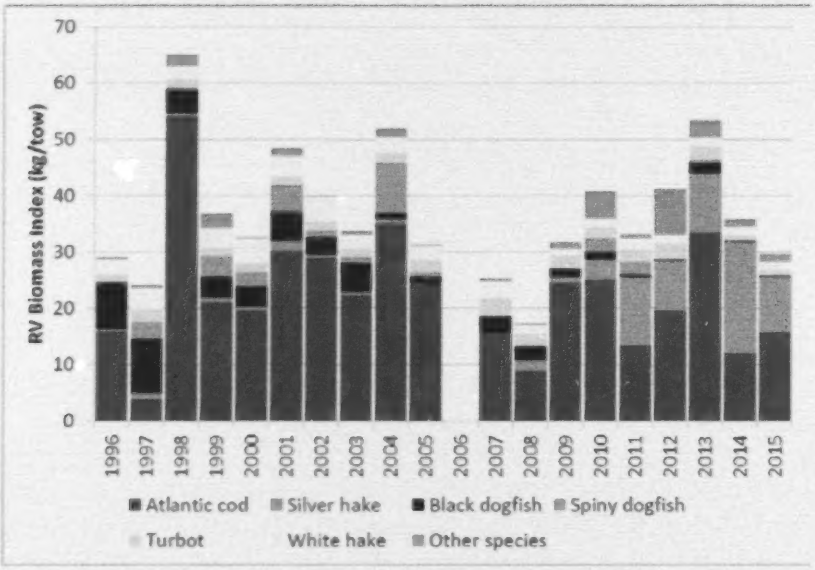

Figure 10: RV biomass from DFO 3Ps Spring survey for Piscivores functional group during the Campelen period. Note the increased dominance of silver hake during 2010-2015.

The limited available diet data suggest that cod has a highly variable diet in 3Ps. Redfish was important in 1993-95, with forage fishes (capelin and sandlance) appearing in 1996 and capelin becoming dominant in 1997. In 2013-15 cod diet has been dominated by sandlance and snow crab (Fig. 11), where consumption of sandlance is associated with smaller individuals, while snow crab tends to be consumed by larger cod. Heavy predation on snow crab has not been observed for other predators (e.g., American plaice, turbot, yellowtail flounder) in the region, nor by cod or other predators in the neighbouring NAFO Division 3O. In recent years, cod diet appears to be increasingly dominated by invertebrates.

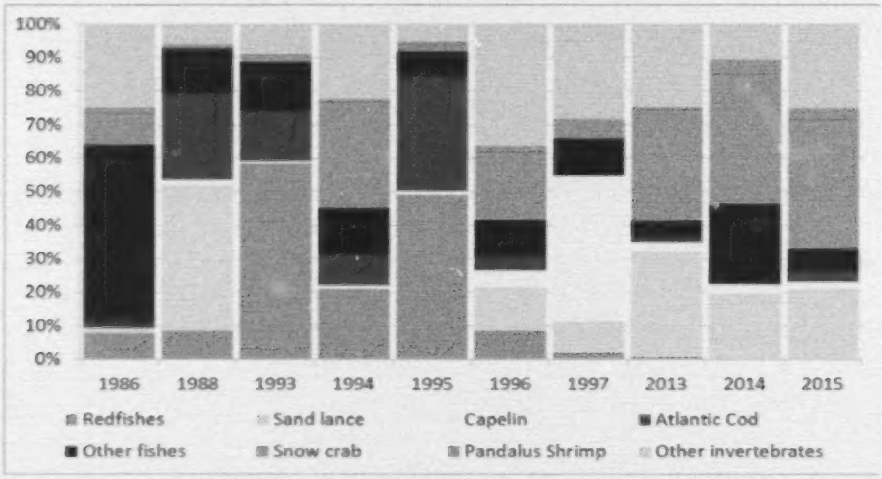

Figure 11: Diet composition of Atlantic Cod in NAFO Subdivision 3Ps (% by mass) from stomach contents collected during DFO 3Ps Spring surveys.

Analyses of meal size and frequency of empty stomachs in 3Ps cod indicate that current meal sizes are of similar (or larger) magnitude than the ones observed during the earlier 1980s, and larger than the ones in the mid-1990s. Conversely, current frequency of empty stomachs is much lower than the ones observed in the mid-1990s. Comparisons between cod meal sizes in 3Ps and 3LNO show that median values in 3Ps are consistently lower than those from 3LNO. These analyses suggest that availability of food may have been a factor in the early 1990s decline, while current status appears to be more likely related to food quality (snow crab is a low quality food, and as a broad generalization, invertebrates tend to be of lesser quality than fishes), although availability of higher quality food may also be at play.

The observed warming of this system, together with recent increases of "warmer-water" species like silver hake and sandlance, the correlated trends among functional groups, and the consistent reductions in average fish size among functional groups, are evidence that the structure of this ecosystem is changing. Although the full impacts of these changes on cod are still unknown, they seem to imply reduced cod productivity. Until the extent and magnitude of these changes can be better understood, it would be strongly advisable to consider higher than usual risk-aversion in the management of 3Ps fish stocks.

Stakeholders Perspective

Inshore fish harvesters attending the assessment meeting reported smaller fish in 2014 and were concerned by the absence of large fish both in the commercial fishery and in the RV data. Approximately 45% of the TAC was not caught in 2014. Consequently, fish harvesters were concerned that taking the full TAC would negatively impact the stock. The abundance of grey seals in Fortune Bay and in areas to the west appears to be high and harvesters were concerned about the potential for higher mortality and lower quality associated with seal abundance.

Canadian fixed-gear fish harvesters' perspectives on the 2014 fishery were compiled based on the results of the telephone survey conducted by the Fish, Food and Allied Workers Union (FFAW). Most fish harvesters surveyed reported that the 2014 abundance was similar to 2013 or was more abundant than in 2013. Catch rates were reported as better than average compared to historically. All harvesters fishing St. Pierre Bank reported cod were in good condition and larger fish were reported from the Bank. The abundance of baitfish (herring, capelin, squid and mackerel) was reported as at a low level and decreasing throughout 3Ps. The exception was sandlance abundance on St. Pierre Bank, which harvesters reported as having good abundance and increasing.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 20-22, 2015 3Ps Cod Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cadigan, N. 2010. Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/015. iv + 43 p.

DFO. 2009. Stock Assessment of Subdivision 3Ps cod. October 2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/063.

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